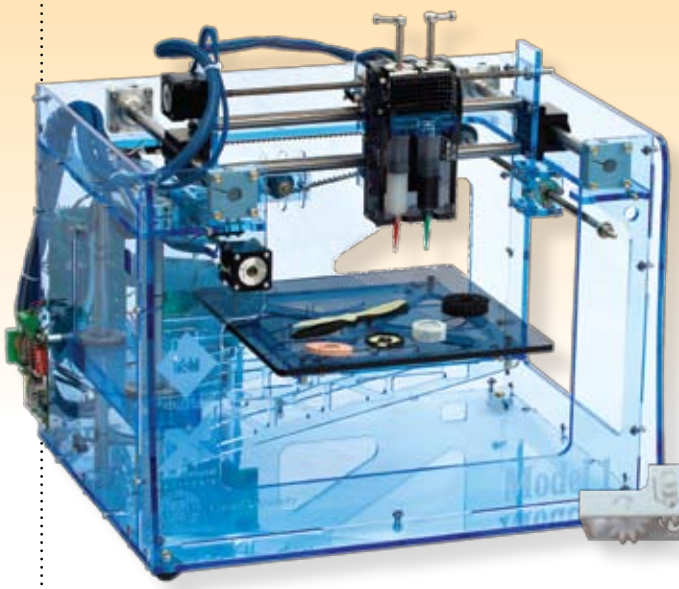
The Democratization



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◀ The Fab@Home fabber employs a relatively new form of manufacturing that builds 3D objects by carefully depositing materials drop by drop, layer by layer.

◀ The design for this gear system is one of many available in the Shapeways database (www.shapeways.com).

Just as the democratization of information through personal computers was a key advance of the 20th century, the democratization of production through improvements in fabrication technologies will be a pivotal development in the 21st century.

Digital fabrication is the process of translating a digital design into a physical object. At one time, digital fabrication required expensive manufacturing plants for computer-aided design (CAD) and computer-aided manufacturing (CAM). But today, personal fabrication systems are beginning to allow individuals access to these same technologies.

Young students have not typically had the opportunity to see their ideas make the trip from concept to physical form. The advent of personal fabrication gives students this opportunity for the first time.

The Society of Manufacturing Engineering concludes that personal fabrication will offer "revolutionary changes for both manufacturers and the everyday consumer, forever changing the way we view manufacturing." The society includes personal fabrication in a short list of innovations that could change engineering, noting that U.S. President Barack Obama has identified this kind of innovation as the key to prosperity.

In *Outliers: The Story of Success,* author Malcolm Gladwell concludes that early access and opportunities to practice are the keys to success in any field involving complex tasks. He notes, for example, that Bill Gates had extensive access to a state-of-the art computer lab in his school in an era when these capabilities were not widely available.

To excel in the field of digital fabrication, students will need early access to personal fabrication tools and opportunities to practice. As fabrication tools become increasingly accessible, students will be able to learn about engineering design and experience the thrill of seeing their ideas realized in physical form.

Computer-Controlled Die Cutting

The inexpensive computer-controlled die-cutting systems that are now emerging can be used to create a variety of shapes and objects from card stock and vinyl. These systems are essentially computer-controlled, electronic scissors. Most schools already have mechanical die-cutting systems, but these machines can only use premade metal dies.

A computer-controlled die-cutting system, such as the CraftRobo, can transform a digital design on the screen into a physical shape. This can expand a learner's ability to construct two- and three-dimensional objects in ways that surpass ordinary office or classroom tools. For example, it can consistently cut in clean, straight lines and transform a variety of media, such as magnetic sheets.

Computer-controlled systems can create perforated lines that students can bend and fold into three-dimensional shapes. They are about the size of an inkjet printer and are affordable at as little as $300. (See Connected Classroom, *L&L*, May 2009.)

# of Production

▲ Fabrication systems allow abstract designs, such as these small orange sculptures, to find tangible form. The blue marble adds perspective of scale (www.bathsheba.com).

Three-Dimensional Printers

Three-dimensional printers use a different principle, building layers of metal or plastic to create a 3D object. In contrast to inexpensive computer-controlled die-cutting systems, the least expensive 3D printer costs several thousand dollars. Fortunately, there are several ways to give students experience using a 3D printer.

Hod Lipson, a professor of engineering at Cornell University, and his students have established an open-source "Fab@Home" initiative (http://fabathome.org). The goal of the project is to make available open-source designs that will allow anyone to construct a 3D printer at an affordable price. The recently released second-generation design makes it possible to construct one for less than $1,500. Users can construct the Fab@Home 3D printer in a day, with no soldering required.

This type of 3D printer, sometimes known as a "fabber," can serve as a rapid prototyping machine. Fabbers make it possible to construct complex objects that would otherwise require special manufacturing tools and resources. According to Lipson, the goal of the Fab@Home initiative is the democratization of innovation.

We plan to explore use of a Fab@Home fabricator in a local school and will report on the results in a future column. In the meantime, we wanted to alert readers about this opportunity and would be interested in hearing about results others have had with this fabricator.

Fabrication via Network

The Shapeways website (www.shapeways.com) provides shape-creation software that allows anyone to create a digital design. Designers can also use their own 3D software to create and upload designs. A community of users is now sharing and exchanging designs in a gallery on the site.

The Shapeways fabrication system employs user-created designs to make objects such as gears, models, and artwork. Users can choose from a database of adaptable parts such as springs and axles that serve as building blocks for constructing complex designs. The organization then sends completed objects to the user via regular mail.

A key advantage of the Shapeways system is that users create shapes without the need for their own fabricators. The range of materials available includes metal and nylon, which cannot be used with fabrication systems typically available to schools.

Fabrication and the Arts

We believe the advent of personal fabrication will affect society in unexpected ways, just as the advent of personal computing did. This will likely extend to the humanities as well as science and engineering. Bathsheba Grossman, a sculptor, describes the effect this innovation has had on her work:

> I don't limit editions.... My plan is to make these designs available rather than restrict the supply. It's more like publishing than like gallery-based art marketing: We don't feel that a book has lost anything because many people have read it. In fact, it becomes more valuable as it gains wide currency and influence. With the advent of 3D printing, this is the first moment in art history when sculpture can be, in this sense, published.

Future of Fabrication

Personal fabrication offers the opportunity to democratize innovation. Schools must provide early access to the tools needed to develop skills required to take advantage of this opportunity. The next Bill Gates or Thomas Edison is undoubtedly in one of today's schools, just waiting to get his or her hands on a fabrication system.

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